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ABOUT STARCH.

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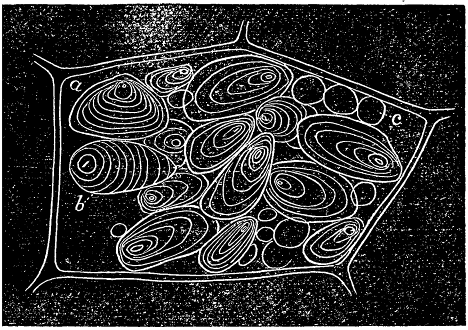
PERHAPS it would be more correct to have our title read "About Starches," for each species of the higher plants seems to have its own characteristic and recognizable sort of starch.

One of the most easily recognizable sorts of all is the starch from the potato. It is very easily got at, too, and requires little

Fig. 72.



or no preparation for its examination. Take a fresh potato and cutting it open, take the thinnest possible slice which one can make with a sharp razor. Deposit the slice on a glass-slip, drop a little water on it, cover it with a thin glass, and it is ready for examination.

Placing the specimen now under the microscope—a magnifying power of 250 diameters does very well—we see (Fig. 72) an im-

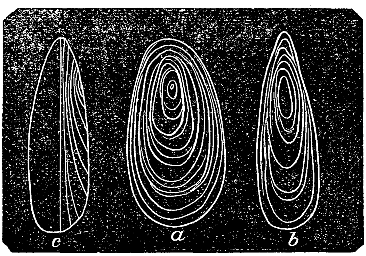
mense number of bodies of two sorts. The most striking are ovoid bodies of considerable apparent size, often showing a series of eccentric rings, the one within the other. Sometimes the rings are seen to be arranged about a dark point or nucleus. Mixed in with these ovoid bodies are large numbers of much smaller disk-shaped ones, without apparent rings. These two sorts of bodies are the starch granules of the potato. It is no unusual thing to find two pretty distinct sizes of starch grains in the same plant. There are intermediate forms of all sizes, but the two sizes referred to so much predominate as to strike the attention at once. The grains are packed in very closely together in much larger cells the cut edges of which can be distinguished, although they are very transparent. Here and there in the section are spots without starch grains and with much finer tissue. These are sections of the vascular bundles where longer and fibre-like cells and vessels which arise from the stem pass through the tuber. Toward the edge of the potato, too, the starch grains are seen to grow less numerous and the cells smaller with thicker walls.

To render the position of starch and cell-walls still more evident, let us apply a little of the aqueous solution of iodine to the specimen. This can be readily done by placing a drop at the edge of the thin glass cover. It will be gradually drawn under to mingle with the water. Meantime its progress and its effect can be watched with the eye at the microscope. Should the iodine not pass readily under the glass cover, its progress can be hastened by placing a bit of blotting paper in contact with the cover on the other side. As it absorbs the water, the iodine will pass in to supply its place. As the iodine comes in contact with the cell-walls they are stained a rich gold-color. At the same time, a series of changes is taking place in the starch. The grains were at first colorless and transparent; as the iodine reaches them, they are stained, first yellow, then red, violet, blue, and finally an opaque black blue, if the iodine is strong enough. Here we have the cell-walls colored one tint, and the starch another, and it is very easy to determine their relative positions.

The use of iodine is the most usual test for starch, and the resulting blue color is just as certain in the blue grains under the microscope as in the starch-paste in use by chemists. If sulphuric acid is added to the specimen, the cell-walls gradually turn blue too.

We have now the position, the general appearance and the usual test for starch. Let us examine it more carefully to see what its structure is. For this purpose take a very little matter scraped from the cut surface of the potato; aim to get only starch and none of the cell-structure. Place this on a clean glass slide, add a drop of water and put on a thin glass cover as before. By careful management of the light, we can probably now see the concentric rings quite plainly. They have the shape of the outline of the starch-grain. If it is egg-shaped, as is usually the case, so are they. If it is almost triangular or linear, as sometimes happens, so are the concentric rings. These rings are sometimes easily seen; at others, only considerable care can bring them out. I have sometimes found them plainer in the starch from a sprouting potato than from others. In potatoes frozen and thawed, they

Fig. 73.



appear distinct. If they can be brought out in no other way, the application of dilute chromic acid will usually show them very plainly. A few lines, scattered among the rest, are generally plainest.

Are these lines simple markings on the surface of the grains, or are they edges of layers one inside the other? In order to ascertain that we must roll them over and see how they look on the edge or on the other side. This is easily done. We have only to incline the body of the microscope a little more, and some of the grains will be carried down by the action of gravity, and will roll over with more or less freedom. If this does not serve, we can press on one edge of the thin cover with the point of a pencil, and a great commotion will be caused among the grains. As this subsides, we can watch some of them rolling over leisurely, now stopping for a moment on the face to give us an opportunity to examine that side, then rolling up on edge and hesitating there

while we survey that side too. Now if the lines are on the surface, a grain like *a* (fig. 73) would look like *b* when rolled up on its side. If, on the other hand, these rings mark the edges of concentric layers, coats arranged like the coats of an onion, they would be arranged in the edge view of the grain essentially as they are in the side view. As the grains roll over, we see very distinctly the rings are concentric yet; the starch grain must be composed of layers one over the other.

If we take a little of the starch from the potato and dry it, without the addition of water, at a temperature of perhaps 150° we shall see a dark point appearing at one end — usually the smaller. This is the nucleus and around it are arranged the concentric rings already mentioned. It has been described as a little pedicle or stem by which the starch-grain is attached to the cell-wall. This was when it was still thought that the grains budded out from the wall, a theory completely disproven now, by what is known of the development and functions of the wall, as well as by specific observations on the formation of the grains themselves. The nuclei have been described too as holes, passing into the interior from the outside, and admitting the materials from which the successive layers were formed from without inwards. If the development of the starch-grain were endogenous, there might be some ground for this hole-theory of the nucleus, but it is now well proven that their formation is from within out, or exogenous. There is no easily accessible specimen at this season of the year, to illustrate this, but writers generally refer to ripening corn, where all the stages can sometimes be seen in a single grain. However, we can easily prove with the specimens under examination that the nucleus is neither a little stem nor a canal. If it were either, it would appear, as we roll the grains, sometimes elongated. As we roll the grains over, by inclination of the stage, or pressure from one side, as before, we see no difference in the shape of the nucleus. It is the same round or angular black spot, occupying the same position from whatever point it is viewed. If we are lucky, we may get a grain up on end, and examine it in the direction of its long diameter. The position of the nucleus and arrangement of the rings remain the same.

What can we conclude concerning the nature of the nucleus from this? It was indistinctly or not at all visible in the fresh grain; it becomes visible on drying, and looks like an air space.

It is in the structural centre of the grain. If the drying is carried far enough, cracks may be seen extending from the nucleus. They generally radiate, looking something like a star. Sometimes one long crack runs the greater part of the length of the grain. The cracks may and may not reach the surface. Taking all these facts together we can draw the fair conclusion; that the layers differ in density; that the inner layers are softer than the outer, because they contain successively more water; that the water is driven off by the heat and the consequent vacuity appears, forming the "nucleus," where there is most water, that is, in the innermost layers; that farther drying causes cracks to appear in the harder layers, the longer the drying the more extensive the cracks.

Further evidence in favor of this explanation of the starch-grain is afforded by the action of hot water and chemicals. If a little starch is boiled, the grains swell, burst and emit much glairy matter. At the same time a thin pellicle sinks to the bottom and is only gradually absorbed. These phenomena can be partially seen in a test-tube. They can be watched under the microscope if the observer has the apparatus for heating his slide without injuring his objectives. For those who are without this apparatus, perhaps the best way is to deposit a little starch with two or three drops of water on a glass slide, and then boil the water down without the application of too much heat. The slide should be allowed to cool before it is placed under the microscope. Starch can then be seen arrested in every stage of solution. One is apparently untouched; another is slightly swelled; another is much swelled at one end; still another is just ready to burst.

A similar series of phenomena can be seen by the application of caustic potash. Arrange a slide as before, for the application of iodine and treat in the same manner. The approach of the reagent causes a great commotion among the starch grains. They become uneasy, dance about, and finally sweep away to the other side of their limits. To see the action of the potash well, one must select a field easily accessible to the reagent, but where the exit of the grains is prevented by an air-bubble or bit of tissue just behind them. That being the case, the grains advise the observer of the approach of the potash by becoming very uneasy. As it strikes them they begin to swell, the swelling extending down their length as the potash advances. The swelling is mostly lateral, and what was an ovoid body before becomes a broad disk.

Meantime the grains warp and twist and writhe about. Separated before by considerable spaces, they now block up the whole field, and their outlines gradually disappear until the whole is a homogeneous mass.

The action of sulphuric acid differs a little. There is the same uneasiness of the grains on the approach of the acid. Meantime the concentric lines grow very sharp and distinct. When struck by the acid, the grains swell until nearly globular, then a fissure appears, generally in the vicinity of the nucleus. The grain is rent from side to side, and a mass of liquid matter with some grains intermixed, shoots out with so much force that it is sometimes carried to a distance of two or three times the diameter of the grain.

From these observations it appears evident: that the outer layers are more dense than the inner; that the semi-liquid interior absorbs water or other fluids by endosmose until the exterior is so much expanded as generally to burst; that the outer layers are much less readily dissolved than the inner.

The use of the polarizing apparatus shows in a striking and beautiful manner that the nucleus coincides with the optical centre of the grain—which might be translated that the layers are really regularly arranged around the nucleus. It also brings out more clearly the rings themselves. If abundance of light is used, and a plate of selenite is inserted between the object and the analyzer, a cross of colors of rare beauty is seen on the grains. If the polarizer is now rotated, the play of colors is very beautiful. The interesting fact to us, however, is that the arms of the color-cross meet at the nucleus.

We have thus seen that the starch grain is an organized body, composed of layers arranged about an eccentric focus, and that these layers increase in density from within out, the innermost being comparatively soft.